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STANDARDS OF QUALITY OF WATER[1]

By Jack J. Hinman, Jr.[2]

In thinking of the quality of a water, it is natural to think first of its potability or sanitary quality, then of its physical attractiveness and finally of its suitability for steam making and other industrial uses. In certain cases the suitability for industrial use takes precedence, but when considering a water supply for a community, choice is commonly determined by the potability and attractiveness, assuming that all sources under consideration can yield a sufficient quantity of water to supply the needs of the community in question, and that the cost of supplying water from the different sources is not subject to too great variation.

The consumer is likely to assume that the water is safe to use and to direct his notice to the physical properties. Color, turbidity, taste, odor, temperature, and to some extent the mineralization make their appeal directly to his senses, and he is apt to judge a water supply on the basis of the conditions with which he happens to be familiar. Local habituation to various types of water that may be common in the particular part of the country in question so frequently determines what will be accepted as satisfactory for public use that the author does not intend to discuss these factors in detail, important though they are. He prefers rather to confine himself to a topic, itself sufficiently broad, that of the standards of the sanitary quality of water supplies, which are supposed to aid in reaching conclusions as to the safety of water supplies for drinking purposes.

It is not the author's intention to attempt to duplicate either the masterly paper by Johnson[3] on "Pure and Wholesome Water," presented to this Association in 1913, or the able paper of Morse and Wolman[4] on "The Practicability of Adopting Standards of Quality for Water Supplies," read before this Association in 1918. Instead of so doing, the author hopes to take up the matter from a rather different angle, and to discuss that which, aside from physical attractiveness, is essential to a good or satisfactory water supply.

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[1] Read before the Chemical and Bacteriological Section at the Montreal Convention, June 24, 1920. Discussion is invited and should be sent to the Editor.

[2] Water Bacteriologist and Chemist, Laboratories for the State Board of Health, State University of Iowa, Iowa City, Iowa.

[3] Johnson, Proceedings American Water Works Association, **33**, 399 (1913).

In so doing, the author realizes the immense difficulties of the question, the bias which experience with the waters of any particular class is likely to give the worker whose observation has been limited, and the practical futility of any attempt to give an entirely definite, clear-cut and readily understandable explanation of the question, so puzzling to many public officials, city councils, and health officers, as to what really is necessary in a satisfactory water supply, when judged from analytical results and similar data.

The confusion is not of recent origin. It is easy to find judgments based on misconceptions or irrelevant or insufficient data. Pliny, for example, seems to have been a bit confused when after declaring that the lightest (and hence softest) water is best, he yet insists that the freezing of a water removes the most refined parts and that water from melted ice is very bad to drink. He goes on, however, to say that boiling is generally admitted to improve the wholesomeness of water and that the best corrective of unwholesome water is to boil it down one-half, a rather heroic treatment.

A text book for health officers, published in 1919, after carefully avoiding definite numerical statements as to the maximum allowable amount of nitrites and so on, gives the following, relative to total solids: "A water containing over 500 parts of total solids per million is not considered fit for household use. Water of good quality usually contains less than 100 parts per million."[5]

To the author's mind, this statement simply illustrates the danger of generalizing too broadly on the basis of experience in a particular locality. To be sure, excessive mineralization is objectionable and finally gets to such a point in some places that the water cannot be used. There are, however, many places where waters of much over 500 parts per million of total solids have been in use for long periods of time without ill effects upon the human organism, whatever the effect on steam boilers may be. Instances might be multiplied where undue emphasis seems to be put on a factor, such as the softness of a water, which, instead of being a necessary condition, is merely a desirable one.

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[4] Morse and Wolman, Journal of the American Water Works Association, **5**, 198 (1918).

[5] Overton and Denno, The Health Officer, 1919.

The author is indebted to Charles R. Henderson, of the Davenport Water Company, for a reference to an old scheme for judging water, translated from the French of Fourcroy, and published in Edinburgh in 1784. It is said that

> Drinkable waters may be easily known by the following character:
> (1) They have a brisk, sharp taste.
> (2) They have no smell.
> (3) They boil easily.
> (4) They make ready pot-herbs well.
> (5) They dissolve soap without forming lumps.
> (6) They deposit nothing or very little by tests.

This is something rather more elaborate than was evidently in the mind of the Mississippi jurist, quoted by Mason,[6] who was of the opinion that any ordinary mortal knew whether or not a water was safe to drink.

Of course experience had shown the folly of such an attitude long before the judge gave his opinion of such matters. A scheme of chemical analysis had probably long been built up. In 1867 when Wanklyn[7] developed the albuminoid ammonia process, a procedure seems to have been quite generally in vogue, although Wanklyn claimed that his book, published in 1868, was the first book published on water analysis. Wanklyn felt that for most purposes a sanitary analysis was complete when it included total solids, or specific gravity, chlorine, free and albuminoid ammonia, oxygen consumed and poisonous metals. He felt that a bacteriological examination was of very little use and that the chemical examination alone was sufficient to pass or condemn a water with very little risk of failure. The rules for the interpretation he said were "tolerably simple."

But the simplicity of the system which Wanklyn proposed, based chiefly on a very dogmatic interpretation of the results of his albuminoid ammonia determination does not meet with general approval at the present time. The determinations have been increased somewhat, but the procedures have increased in number even more.

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[6] Mason, Science, 21 (New Series), No. 539, 648 (April 28, 1905).

[7] Wanklyn, Journal of the Chemical Society, **5** (Series 2), 593, 1867.

Thus, on account of the lack of uniformity of methods, an attempt was made to standardize methods of water analysis as early as 1887 by the American Association for the Advancement of Science.[8] This work seems to have been suggested by a paper of Prof. W. H. Seamon before the Chemical Section of the American Association for the Advancement of Science at Buffalo.

In a sense this report and one or two which followed were the forerunners of our present "Standard Methods of Water Analysis," now gotten out by the American Public Health Association. The present methods, according to the preface of the first edition, apparently resulted more directly from the efforts of Dr. Wyatt Johnson, of Montreal, who was active in the work from 1894 until his death in 1902.

The first appearance of "Standard Methods of Water Analysis," in book form was in 1905. The fourth edition is just off the press within the last few months. The Standard Methods, as everybody knows, consist of sections devoted to chemical, bacteriological, and microscopical examination. The last named is by far the shortest section. These methods have generally been in accord with current practice and have done a great deal toward unifying the procedure in water laboratories. In 1905 a scheme was proposed outlining the tests that the committee deemed necessary for various waters, based on the character, variety of treatment, and so on. Recent inquiries have shown that the procedure in the state[9] and city and water works[10, 11] laboratories is still far from uniform. The greatest variation is, naturally enough, along the line of the bacteriological examination. Here, the manner of obtaining bacterial counts and the tests employed for the members of the B. coli group are varied over a rather large range. However, the media employed seem to be generally prepared according to the "Standard Methods of Water Analysis."

The public, officials, and to a large extent the physicians, still persist in the belief that a water examination is much like an analysis of an iron or steel, and that the less the analyst knows about the source and nature of the sample, the more reliable his work will be.

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[8] Caldwell, Journal of Analytical Chemistry, **3**, 398 (1889).

[9] Morse and Wolman, Journal of the American Water Works Association, **5**, 198 (1918).

[10] Hinman, Journal of the American Water Works Association, **5**, 133 (1918).

[11] Norton, Journal of Infectious Diseases, **23**, 344 (1918).

Every water analyst occasionally receives water samples in containers which range from 2 drachm vials, through perfumery bottles, medicine bottles, mason jars, and jugs to 5 gallon demijohns. Formerly the whiskey flask was a favored receptacle. Every imaginable degree of care in the preparation of the containers, from actual sterilization to a mere rinsing, could be expected.

Occasionally deliberate "doctoring" of samples of water for examination is practised. The author remembers one case in which urine was added to a sample of well water in the hope that the water might be condemned, and the owner of the property be forced to put in the more convenient city water. In other cases various materials have been added to samples of city waters, sometimes by city councilmen, as continued good reports upon the city supply caused the analyst to be suspected of collusion with the water department to provide reports invariably satisfactory.

The difficulties in the path of the analyst are great enough, even under the best conditions of collection, an accurate description of the source of the sample, and prompt examination. While the value of the sanitary survey has been admitted for a very long time, it has been, and still is, the practice of many State Boards of Health to let the sanitary survey, if it can be called such, be made by the sender of the sample who may, by long association with conditions or lack of appreciation of sanitary matters, be totally unfitted to transmit correct information to the laboratory. This is, of course, practised, in most cases, because of small appropriations and a desire to extend the work to as many of the citizens of the state as possible. The practice has been condemned by many workers and Whittaker[12,13] has shown the chance of error to be relatively great. It is undoubtedly true that in order to obtain the most reliable results, a sanitary survey of each supply should be made and the samples of water collected at the same time by a trained observer. The examination of the water should be begun at the earliest possible moment and the results of the analysis should be interpreted in the light of all the information available.

Fixed standards are at best reversions to rule-of-thumb methods, since they attempt to pronounce a judgment upon a water supply, while utilizing only a part of the evidence. They are demanded

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[12] Whittaker, American Journal of Public Health, 7, 785 (1917).

[13] Whittaker, Journal of the American Water Works Association, 7, 278 (1920).

chiefly by the non-technical public on account of the convenience in enforcing legal measures, such as control of water supplies and the guarantees of filter manufacturers.

Standards may be divided into three groups on the basis of the way in which they approach the matter in hand:

1. Ideal standards. Those which are intended to give the values which would be found on an analysis of a water of great natural purity. An example of this sort of standard is the standard of the Hygienic Laboratory of the University of Michigan.[14]

2. Normals. These are standard values which have been found to be characteristic of pure waters from similar sources in areas more or less narrowly restricted and from approximately the same geological horizons. An example of this type may be found in the local standards of Haines for water on the west bank of the Delaware River near Philadelphia.[15]

3. Limit standards. These are standards expected to show the maximum amounts of various matters permissible in waters. There are many examples of this sort of standard. One of the most typical sets of standards is Bartow's suggested limits for Illinois waters.[16]

It is necessary, of course, that it be well understood what sort of a standard is meant. Ordinarily we think of limit standards when the word standard is used. For the normal type, the words, normal or normal value, should be sufficient.

The normals to be true values must be obtained by the summarizing of a long series of analyses of waters which clinical experience, sanitary survey and all other data show are typical unpolluted waters of the region. Just how large an area should be included in the determination of the normals would of course depend on the local circumstances. One recent report involved the determination of isochlors for an area of more than 20,000 square miles on a basis of the examination of only 62 samples.[17] Depth, or preferably the geological horizon, should be known for all well water sources, as this information may be more important than the areal distribution. Normals cannot usually include bacterial results when dealing with more than one supply, although the relatively great bacterial purity of ground waters must be noticed.

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[14] Vaughan, Public Health, Michigan, **7**, 9 (January–March 1912).

[15] Haines, Journal of Analytical and Applied Chemistry, **5**, 289 (May 1891).

[16] Bartow, Bulletin of the University of Illinois, Water Survey Series, No. 7, 109 (1909).

[17] Vickery, Proceedings and Transactions Nova Scotia Institute of Science, **14** (iv), 335 (1917–8), through Chem. Abstracts **14**, 1719 (1920).

In the matter of limit standards, both chemical, bacteriological and combined standards have been proposed, adopted and made part of ordinances, regulations of State Boards of Health, and given the force of state statutes. Sometimes they have been made after considerable experiment in a particular locality, sometimes after consultation with experienced workers, sometimes apparently in a purely arbitrary manner. Sometimes the standard has been made for one particular supply and sometimes a general standard has been attempted. Generally speaking, a local standard is of very restricted interest, but when a standard is applied to the waters of a state or country, especially our own, it is a matter of vital importance to the men of the water supply industry.

Nevertheless the making of local standards, accompanied by penalties is of general interest. Sometime ago Jordan[18] called attention to City Ordinance 1769, of the City of Des Moines, Iowa, passed January 11, 1911, and City Ordinance 7113 of Omaha, Nebraska. The Des Moines supply is a chlorinated infiltration gallery water and the Omaha supply is river water, coagulated, settled, and chlorinated. After a period of three months in the case of Des Moines and fifteen months in the case of Omaha, the water furnished was required to meet the following conditions:

	DES MOINES	OMAHA
Total solids	450.0	475.0
Free ammonia	0.04	0.04
Albuminoid ammonia	0.10	0.05
Oxygen absorbed in 10 minutes at 100°C	2.00	2.00
Chlorine	3.5	
Nitrogen as nitrites	0.00010	None
Nitrogen as nitrate radical (NO_3)	0.75	
Bacilli per cubic centimeter	50.0	50.0

The water must be clear without suspended matter and free from "any gas-producing bacteria, colon bacilli or other pathogenic bacteria."

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[18] Jordan, Proceedings Indiana Sanitary and Water Supply Association, 8, 94 (1915).

The Des Moines ordinance carried a provision entitling the City Council to make examinations when desired but requiring examinations to be made at least once a week. The violation of the ordinance was made a misdemeanor, punishable by a fine of $100 or by imprisonment not exceeding 30 days in jail. Each day unsatisfactory water was furnished was to constitute a separate offense. This is the most complete set of local standards which have been duly enacted, so far as the author is aware.

Neither the Des Moines nor the Omaha ordinance specifies what media or temperature shall be used for the bacterial counts, though the ordinances specify that the methods of the American Public Health Association shall be used, and that lactose bouillon shall be used for fermentation tests.

The Des Moines and Omaha waters are treated waters, so that the bacterial results, and not the amounts of chlorides and nitrogen, are essential information in judging the quality of the water. Everybody knows that the Raccoon and the Missouri are polluted rivers. The chlorides of the raw waters and the vagaries of the nitrogen determinations are quite beyond the control of the plant operators. Then, too, while at least one writer has claimed to be able to determine the number and class of the bacteria present in a water by the nitrogen factors, the author believes that most water analysts would consider the process open to the criticism that it at least lacked accuracy.

Whatever the framer of the ordinances has in mind with regard to the practical working of the proposed standards, had the nitrogen determinations or the determination of the chlorides been at any time above the values set forth, the water would not have been of "standard quality." Then those in charge of the water works might have been forced to face the penalties as specified in the ordinances or else show that the ordinances were not valid. In either case the effect upon the public opinion would have been much the same.

These standards were adopted about three years before the author had had any experience with water supplies in that particular part of the country, and he has little personal knowledge of the actual enforcement of the ordinances. The ordinances have been introduced here solely to illustrate the point that legally established standards of this nature may be impossible of fulfillment, and, unless interpreted with so great leniency as to be practically worthless, may result in the condemnation of a supply which is entirely safe. Moreover, standards of this sort may easily constitute an element of offence in the hands of unscrupulous persons, who may wish to discredit the water supply.

In the case of table waters which are put upon the market with special claims as to purity, or perhaps as to their mineral contents, any material departure from the purity or mineralization claimed, may constitute an offense under pure food laws. The United States Department of Agriculture standard, of which more will be said later, was prepared for the purpose of regulating the purity of table waters, and prosecutions are brought against dealers whose waters do not come up to the requirements. This standard has the same bacterial requirements as the United States Treasury Department standard for water supplied by common carriers to passengers in interstate traffic, but it also carries certain chemical provisions, "special significance being attributed to the presence of nitrites, free ammonia in excess of 0.05 milligram per liter and to an undue amount of organic matter." Since most states have adopted the food standards of the United States Department of Agriculture as their own standards, this standard for table waters automatically becomes their standard also.

Article 1935 of the city code of Evanston, Illinois, contains a local standard for table waters: "No water shall be sold or offered for sale for drinking or other domestic purposes which contains sewage forms or pathogenic bacteria or contains more than 100 bacteria per cubic centimeter in a total seven day count at a temperature of 20 degrees centigrade on agar or which contains nitrates or nitrites in such amount as to indicate contamination as ascertained by the standard methods of water analysis." The penalty is a fine of not less than $10 nor more than $200.

Local standards of plant operation are in most cases fundamentally different from the standards given above. They may never be written down at all, but may exist only in the mind of the operator in charge. These plant operation standards represent what the operator in charge expects of his plant in the light of its past performance, treating the water regularly handled. The local source of the water, the peculiarities of the plant, and the operator's own knowledge of current water works practice are usually the determining factors. Naturally, standards of this type for water plants vary widely. Some operators are apparently satisfied if the water pumped is "bright and clear," others demand freedom from iron, a certain maximum hardness or a high degree of bacterial purity. Tabulations in the author's paper[19] on "American Water Works Laboratories" contain lists of these lower operation standards. It is in the smaller plants where we may expect to find the local operation standards at the lowest values. Commonly a reasonably clear water is satisfactory to the operators of many of these plants unless the State Board of Health or some other agency calls their attention to their delinquency.

Local operation standards frequently contain the obsolescent term, "percentage of bacterial removal;" sometimes the "B. coli index." At times the index is calculated upon a few samples; at other times it is based upon the examination of an adequate number of samples with sufficiently great variation in the size of the portions tested for the colon group organisms. Sometimes the colon tests are mere presumptive tests; at other times all gas-forming bacteria are subjected to complete identification tests. The importance of the latter, will, of course, depend upon the local experience, being greatest where the atypical gas-forming bacteria are found much more frequently than the true colon-type organisms. Likewise the complete identification is more significant in gas-forming bacteria isolated from treated waters than in those isolated from ground waters where either type indicates a contamination presumably from the surface. It is perhaps not amiss at this point to insert a table of results upon an Iowa city water which is both filtered and

WATER	TEST	NUMBERS OF TUBES				
		0.01 cc.	0.1 cc.	1 cc.	10 cc.	Total
Raw	B. coli	9	33	143		185
	B. aerogenes	1	4	30		35
	Other gas-formers	5	6	28		39
	Negative	38	25	144		207
	Total	53	68	345		466
Treated	B. coli			2	5	7
	B. aerogenes			0	4	4
	Other gas-formers			1	59	60
	Negative			642	260	702
	Total			645	328	973

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[19] Hinman, Journal of the American Water Works Association, 5, 133 (1918). The author has also filed recently with the Secretary of the Association blueprints giving a more complete record of local operation standards.

chlorinated. The difference in the character of the gas-forming organisms in the raw and treated waters is readily apparent, as has been noticed by other observers with other waters. Differentiation between Bacillus coli and Bacillus lactis aerogenes was made by means of eosine methylene blue agar plates.

The value of the B. coli index calculated upon the presumptive test alone would be a rather different value from the index calculated upon the confirmed test.

The author does not believe with Wells[20] that the fact that much of the mathematical work on the probable numbers of bacteria or B. coli group organisms has been done by engineers accustomed to higher mathematics will cause bacteriologists to neglect this sort of work, or to fail to attempt to understand and apply the principles involved. He does believe that the remarks of Doctor Mason[21] regarding the small value of elaborate calculations based on insufficient data or a few samples, involving large probability of individual error, should be kept in mind. The author particularly objects to the practice, to which he has of necessity at times been a party, of figuring the number of B. coli type organisms per 100 cc. on the basis of the examination of one or a few samples of water collected from a railroad supply during the six months period specified.

It is only fair to Phelps, the author of the system commonly used for calculating the B. coli index in the United States, to note that in the original article[22] Phelps definitely stated that his method was of value only for work involving large numbers of samples from a single supply, and that for a single sample or for a few samples it was worthless.

The work of Whipple,[23] Wolman,[24] McCrady,[25] Greenwood and Yule,[26] Stein[27] and others is highly significant of the trend of ideas on water examination. The mathematical summarizing of results of water examinations and of plant operation is the subject of a large amount of endeavor. Something useful is bound to come of it ultimately. The problem involves two apparently opposed types of data. What we need, of course, is a system which will enable us to grasp quickly, but accurately, what sort of results a particular plant is giving in operation, but its response to unusual or accidental conditions is of great importance, and the value of the information obtained at such times should not be destroyed by smoothing to a general average.

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[20] Wells, American Journal of Public Health, **9**, 956 (1919).

[21] Mason, Journal of Industrial and Engineering Chemistry, **11**, 486 (1919).

[22] Phelps, Proceedings American Public Health Association, **33**, 9 (1907).

[23] Whipple, Journal of the Franklin Institute, **182**, 37 (1916).

[24] Wolman, American Journal of Public Health, **6**, 1153 (1916). Journal American Water Works Association, **4**, 200 (1917). Journal American Water Works Association, **5**, 272 (1918).

[25] McCrady, Journal of Infectious Diseases, **17**, 183 (July, 1915). Public Health Journal, **9**, 201 (May 1918).

[26] Greenwood and Yule, Journal of Hygiene, **16**, 36 (1917).

[27] Stein, Engineering News-Record, **82**, 1106 (1919). American Journal of Public Health, **8**, 520 (1919).

The possibility of accident in water works operation is a tremendous subject, not without its bearing on water supply standards. In this connection the author does not mean stoppage of the pumps or the breaking of a main. It is accidents involving the quality of the water itself to which reference is made, for, as Houston[28] has recently said, "it is obvious that to allow any adventitious water to enter a water supply subsequent to its purification is fraught with potential danger, and danger which even the most astute expert may be powerless to gauge." The care and expense employed in purifying a water supply are largely wasted if the purified water is subject to contamination by means of connections to impure private water supplies, by leakage into reservoirs or clear-wells, by careless storage, or other conditions which follow faulty design or construction. Lists, such as that of the Minnesota State Board of Health,[29] setting forth some of the commonly found defects of construction are suggestive.

When we attempt to consider a question such as this, we find ourselves at once confronted by the question of the standardization of the sanitary survey. The work that Horton and Chase[30] have done on the scoring of water supplies in New York State and the suggestions of Wolman[31] relating to a possible index number system for rating water purification plants are interesting, if not of general applicability at the present time.

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[28] Houston, Reports on the Progress of Applied Chemistry, Society of Chemical Industry, **4**, 477 (1919).

[29] Report of the Division of Sanitation, Minnesota State Board of Health, 1916–17, page 367.

[30] Horton and Chase, American Journal of Public Health, **7**, 380 (1917).

[31] Wolman, Journal of the American Water Works Association, **6**, 444 (1919).

Surveys are not now standardized, of course, but even so, their value cannot be questioned. It has long been appreciated that if the possibility of pollution of a supply can be detected by a survey, an analysis, other than to attempt to determine the strength of the contamination, is usually unnecessary. Whittaker[13] has shown that unsatisfactory conditions are often more successfully detected by the survey than by the analysis of the water, although the latter has its own definite importance.

The possibilities of intermittent pollution of ground waters, at intervals separated by periods when analyses may yield satisfactory results, and the variation of efficiency of purification at most water purification plants must be recognized. An analysis may tell what the condition of a particular liter or gallon may be, but that gallon or liter was collected at a particular moment, on a certain day, at a particular place. There is oftentimes a very strong probability that the sample as taken did not represent, in an exact fashion, the water being supplied all over the system at the time the sample was collected, and that the variation over a period of a year might be very great indeed. But the sanitary survey may help in securing samples more truly representative than samples taken without due regard to the peculiarities of the supply and, even more important, it may point out the possibilities of future difficulties, with possible suggestions as to the removal of the danger before anything of a serious nature has developed. It is, indeed, very doubtful if any supply should be passed or condemned without a thorough sanitary survey. It is quite as important in judging a supply to know that the water is produced and distributed in such a manner that periodical variation or accidental contamination cannot be expected to prejudice the quality of the water, as it is to know that one or more samples submitted to analysis show nothing to indicate that anything dangerous to health is present in them.

For the information of the Committee on Official Standards of Water Analysis of the American Water Works Association, and for the preparation of this paper, the author has recently made an inquiry of a number of city, state and plant authorities as to their experience with water supply standards. A large amount of information was courteously furnished which has been summarized in two tables. Table 1 details the results having reference to the State Water Laboratories, and Table 2 details those referring to the plant and city laboratories. Copies of these tables have been filed with the Secretary of the Association.

Of the state water laboratories six apparently use the United States Treasury Department standard for water supplied by common carriers to passengers in interstate traffic:.three use more rigid standards, but one of these is readily modifiable: seven use the United States Treasury Department standard or its variant, the United States Department of Agriculture standard, but not in a hard-and-fast manner: seven use less rigid standards; nine have no standards at all; three were not definite enough in their statements to permit classification into one of the above groups. It is in these state laboratories that one would expect to find the greatest use of standards, because they offer an apparently satisfactory means of distinguishing good from bad water supplies, and offer something of a tangible nature for the making of rules and regulations, and the control of public water supplies.

It is hardly worth while to define the United States Treasury Department standard for water supplied by common carriers to passengers in interstate traffic.[32] (Not more than 100 bacteria per cubic centimeter in 24 hours at 37°C., on agar; not more than two out of five 10 cc. plantings positive for B. coli group organisms. Media used according to Standard Methods of Water Analysis, A. P. H. A., 1912.) The United States Department of Agriculture standard is perhaps less well known. Its provisions have already been given.

When the bacteriological standard of the Treasury Department was adopted on October 21, 1914, as the work of a commission of experts, it was proposed to follow it with a chemical standard. This was later abandoned as impractical on account of the difficulty of securing an agreement upon the factors to be used. Hanford and Bartow[33] published a suggested set of chemical standards based upon experimental work on railroad water supplies in Illinois.

At the time the Treasury Department Standard was adopted it was expected to use it as a hard-and-fast laboratory standard setting the maximum amounts of bacterial content permissible. Judgment was to be made based upon one sample of water, taken from the water tanks of trains and other sources which would preclude a sanitary survey of the source. The amendment of 1919,[34] which requires a survey, is sufficient evidence that, although it was felt at the time of the promulgation of the standard that a rigid enough standard had been devised to allow for all conditions, it was found that the standard was open to error. The recent statement of Senior Surgeon J. O. Cobb, United States Public Health Service, before the Indiana Sanitary and Water Supply Association[35] is significant of the newer trend of official ideas on the subject of the standard:

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[32] United States Public Health Reports, **29**, No. 45, 2959 (Nov. 6, 1914).

[33] Hanford and Bartow, Bulletin of the University of Illinois, **14**, No. 5, Water Supply Series No. 13,256 (October 2, 1916).

[34] Amendment No. 8 to U. S. Interstate Quarantine Regulations, July 14, 1919.

> Water supplies heretofore have been passed upon by bacteriological standards. Very little attention has been paid to survey standards which engineers would likely set. I think the time has come to adopt the engineering point of view. The bacteriologist will only be a checker-up and I think I can convince you . . . . that we should adopt the survey method of accepting a water supply rather than the bacteriological.

This is a decided change of front over the original method, and one which seems to the author to be more logical and more likely to meet with the approval of plant operators, whether or not their supplies will pass the requirements at the present time. The Treasury Department standard is of interest to every water works operator in the United States, for although it was announced in the original notice that the standard was to be applied only to the water supplies used by railroads which had the opportunity to fix their points of filling tanks, and were not compelled, as the municipality might be, to take the water at hand for use, the effect of the posting of notices in stations and the condemnation of local waters has been to force the standard upon the local plants through the action of governmental prestige and public opinion. In so doing the standard has been useful in raising the quality of some water supplies, though it may have worked hardship upon some satisfactorily conducted plants. It was the author's understanding that the standard was to be applied only to the supplies from which interstate carriers took their water. It now appears, however, that the Public Health Service expects to control supplies of carriers whose lines do not cross state borders on the ground that they may carry interstate passengers and become in effect interstate carriers. The basis for this last statement is found in a foot note to a recent report on the railroad water supplies of Iowa.[36] If this is correctly understood, the Treasury Department standard will be extended to a large number of additional water supplies.

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[35] Cobb, Proceedings Indiana Sanitary and Water Supply Association, 12, 12 (1919).

Of the 168 city plants from which reports were received by the author, 46 claim to operate continuously to the Treasury Department standard, 4 work to a more rigid standard; 16 work to a less rigid standard; 45 do not claim a standard and 44 give standards whose position with respect to the Treasury Department standard is difficult to determine.

When it comes to the expression of a direct opinion on the Treasury Department standard, 47 consider the standard reasonable, if those who claim to reach the standard practically 100 per cent of the time are included as considering it so: 19 are in favor of the standard with reservations; 21 are opposed to the standard and 81 express no opinion. The 19 who favor the standard with reservations nearly all wish a standard that is flexible; that will take into consideration the natural advantages and the natural disadvantages of the supply. As the standard of the Treasury Department was originally conceived, this desired flexibility was impossible, but with the amendment of 1919, it is possible that a certain degree of flexibility may be introduced. Several of those who are opposed to the standard base their opposition upon the same point. As the standard departs from its rigidly fixed character under the 1919 amendment it is thus reasonable to believe that it will receive their approval

One man states as his opinion that "if a (fixed) standard is adopted for general application, it must be one which can be met by every water company. Then it would have to be so broad and liberal as to have no real value." It is felt that a standard in its fixed form might be too high for some plants actually furnishing a safe water, and yet be so easily met by certain others that the latter might become too lax in their methods.

Some others who expressed opinions in the matter are even more forceful in their condemnation of the whole subject of standards. For example there are the following statements: "Hire a man who is capable of judging conditions and throw rule-of-thumb methods away," and, "The more I see and hear of so-called standards for water, the less I think of them."

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[36] Footnote to Wagenhals' Report to the Iowa State Board of Health on Water Supplies Used for Drinking and Culinary Purposes by Common Carriers in Interstate Traffic, page 2 (February, 1920).

McLaughlin[37] has advocated the application of the Treasury Department standard to the effluents of filter plants prior to their treatment by any germicidal agent, such as calcium hypochlorite or liquid chlorine. This would considerably increase the difficulty of many plants in reaching the prescribed degree of bacterial purity. To be sure it would introduce a large element of safety, probably well worth while in plants suspected of being carelessly operated. Ohio has recently begun the use of a set of standards including one for filtered water before chlorination. This particular standard seems to be, in its essence, the same as that of McLaughlin.

The Treasury Department standard was adopted as the standard of the American Expeditionary Forces in France. Its use there was apparently generally satisfactory. Where unfiltered water was used, it was sometimes necessary to use quite heavy chemical treatment in order to get the water within the specified limits. The experience of the soldiery with Lyster bag chlorination was such, however, that a dose of chlorine which would not be used in city water works practice could be used in France without undue complaint. It was found, too, that the Treasury Department standard in regard to freedom from B. coli group organisms was approximately equivalent to the apparently more rigid French standard. The French commonly used phenol broth for their B. coli tests, instead of lactose bouillon, and the inhibitory action of the phenol was believed to be responsible for the difference in the apparent results.

The International Joint Commission on the Pollution of Boundary Waters, in its study of the water along the boundary between the United States and Canada, employed a tentative standard for reasonable burden on filter plants in so far as the character of the raw water was concerned.[38] This standard, which was adopted on the advice of some of the most eminent engineers of the water supply industry, was an attempt to gauge, in a rough manner, the extent of the sewage contamination of the raw waters which filter plants could be reasonably expected to handle in a satisfactory manner. The standard provided that in order to be a suitable water for filtration, a raw water should not show more than 50 per cent positive tests for the B. coli group organisms when 0.1 cc. quantities were considered and frequent examinations were made to determine the character of the water over the period of a year. Thus it would correspond to a yearly average of 500 B. coli group organisms per 100 cc. This standard as a tentative limit of reasonable burden, could not be said to be a fixed standard of the character of the United States Treasury Department standard for water supplied by interstate carriers.

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[37] McLaughlin, U. S. Public Health Reports, **29**, No. 26 (June 26, 1914).

[38] Final Report of the International Joint Commission on the Pollution of Boundary Waters, Washington, 1918, page 14.

There are those who see in the present apparently chaotic state of water supply standards the result of attempting to build a structure involving the use of absolute values, upon a foundation of determinations which, as Bertarelli[39] has said, have often only a purely doctrinal value. The actual causative organisms of water-borne diseases, with the possible exception of the Vibrio cholerae, remain elusive to methods of detection which are sufficiently simple, rapid, and accurate to permit of their use in routine water examinations. Elaborate generalizations, such as those of Kinnicutt,[40] based on the nitrogen determinations, have been attacked in such papers as that of Leighton[41] on the Futility of a Sanitary Water Analysis. And yet we have available tools, in our methods of water examination which, though perhaps open to error if incorrectly used, are nevertheless, good and useful and capable of giving us valuable information.

We must not allow the good points of the methods that we have to be obscured by the fact that under certain circumstances they do not fit the conditions. In the case of determinations which are most useful in following the condition of raw waters, chemical methods, if applicable, can avoid the loss of time which as yet cannot be avoided when dependent on bacterial methods. In different places it is natural that different methods are followed as most satisfactory. Thus Calvert[42] says that for distinguishing one water from another or detecting any important change in the mixture of waters at the plant of the Indianapolis Water Company, the determinations alkalinity, chlorine and nitrites are most useful. At another plant alkalinity and iron are the most useful, at another the free ammonia is depended upon, and at another the oxygen consumed is considered to give the best indication of changes of importance in the raw water. These determinations are especially useful where waters from the various sources are practically clear and colorless. Where mixtures of streams of decidedly different color and turbidity are handled, the value of the color and turbidity measurements is self-evident. For general purposes different workers consider different methods preferable. This is natural, of course. Some hold tightly to the orthodox nitrogen determinations, while others discard them, claiming that they have no value. But the fact that these determinations have no value in one locality may not destroy their usefulness in another. It is when these determinations, whether of the nitrogens or other factors, are applied to general fixed standards that the great likelihood of error arises.

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[39] Bertarelli, Rivista di Ingeneria e di Edilizia Moderna, **16**, No. 21 (Nov. 15, 1915) through Bulletin Mensuel Office International de l'Hygiene publique **8**, No. 2, 386 (1916).

[40] Kinnicutt, Science, **23**, New Series, No. 576, 56 (January 12, 1906).

[41] Leighton, Biological Studies by the pupils of William Thompson Sedgwick, Boston, 1906, page 36.

[42] Calvert, American City, City Edition, **22**, No. 6, 576 (June 1920).

Bacterial counts and determinations of the B. coli group organisms are useful, too. Many analysts would undoubtedly say that they constitute our chief tools in determining the sanitary quality of a water. But they, too, are liable to a certain amount of error in the hands of those who are unfamiliar with local conditions. In the South, or where the temperture approaches the body temperature, rapid aftergrowths of the organisms originally present in the water and surviving chlorination, and also the multiplication on storage of the few organisms present in well waters, may be expected. This is in line with the statement, made many times before, that while the actual number of bacteria in a water is of value in judging the water, high bacterial counts are not necessarily associated with dangerous, or even objectionable, contamination. Haskins,[43] among others, has objected to too great emphasis on the B. coli group organisms, especially when these forms seem to be restricted to soil and grain types, and the sanitary survey shows no probable source of pollution. Then there are the spore-bearing gas-formers to be considered, with the reduction in the value of the unconfirmed presumptive tests in the localities where these forms are predominant. With a fixed standard in use, proper provisions for these matters is difficult, to say the least.

Standards, if prepared, must have a certain amount of flexibility and depend in large part upon the sanitary survey as made by someone who is experienced in such matters. And the object in view must be to get a safe water, from a suitable source, in a manner which represents the best operation of the plant. It is the author's belief that the greatest possibilities along the line of standards are in the direction of purification plant operation and construction.

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[43] Haskins, Engineering News-Record, **78,** 312 (1917).

In spite of its general character, the author feels that in closing this discussion it is well to repeat the definition of a satisfactory water which was proposed by the Association's Committee on Official Standards of Water Analysis:

> A water which is reasonably free from noticeable color, odor, taste, and turbidity, which is reasonably free from objectionable salts in solution, which is free from injurious effects upon the human body, and which is produced and distributed in such a manner that its quality is practically certain to be maintained continuously in spite of accidents which can be expected in the operation of the plant.